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THE AMERICAN

METEOROLOGICAL JOURNAL.

VOL. VIII. ANN ARBOR, MICH., SEPTEMBER, 1891. No. 5.

ORIGINAL ARTICLES.

MOUNTAIN METEOROLOGY (CONTINUED).*

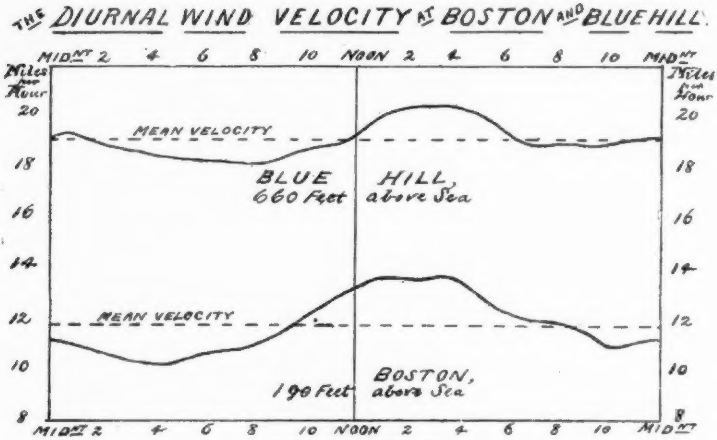
[CONTINUED FROM THE AUGUST NUMBER.]

In an hour it would evidently be impossible for me to do more than to enumerate the chief results of meteorological observations at high altitudes. Therefore I have preferred to consider one or two subjects more in detail, and in order to bring them nearer home I shall, in several cases, refer to the observations made at the Blue Hill Observatory, without intending thereby to magnify their importance.

The two subjects which I have selected as most familiar to every one are, together with the allied subject of atmospheric pressure, wind and temperature; and I shall now ask you to consider some of the modifications which occur in them as we rise into the atmosphere.

First, as to *Wind*. That there is a great increase of wind as we rise above the earth, on account of the retarding effect of friction with the ground, is well known to us all. Experiments were made by Mr. Stevenson, of Scotland, several years ago, to ascertain the rate of increase. In order to do this, he placed anemometers to measure the velocity of the wind at different heights above the ground upon a tall pole in an open field. The experiments were only carried to a height of fifty feet, but the curve, above fifteen feet, is a parabola, with its vertex seventy feet below the ground line.

*Extracts from a series of three lectures delivered before the Lowell Institute, of Boston, in 1891, by A. Lawrence Rotch.


THE DIURNAL WIND VELOCITY AT BOSTON AND BLUE HILL.
MIDNT 2 4 6 8 10 NOON 2 4 6 8 10 MIDNT
Miles per Hour
20
18
16
14
12
10
8
MEAN VELOCITY
BLUE HILL, 660 Feet above Sea
MEAN VELOCITY
BOSTON, 190 Feet above Sea

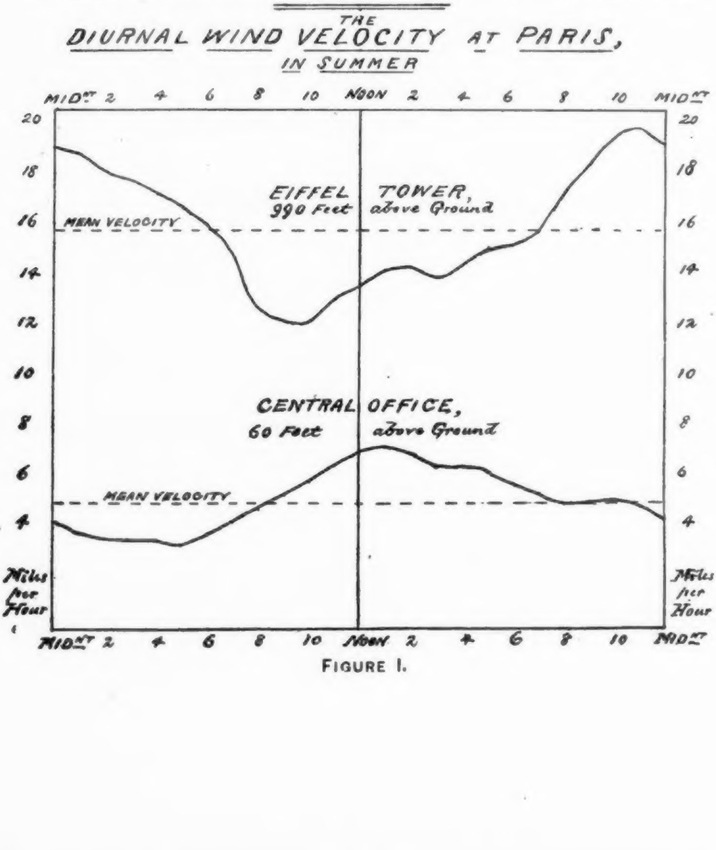

THE DIURNAL WIND VELOCITY AT PARIS, IN SUMMER
MIDNT 2 4 6 8 10 NOON 2 4 6 8 10 MIDNT
20
18
16
14
12
10
8
6
4
Miles per Hour
EIFFEL TOWER, 990 Feet above Ground
MEAN VELOCITY
CENTRAL OFFICE, 60 Feet above Ground
MEAN VELOCITY

FIGURE I.

The decrease of wind velocity with height is slower as we get away from the retardation caused by the asperities of the earth's surface and of course varies with the situation of the station. On Blue Hill the average wind velocity is two-thirds greater than at Boston, about 500 feet lower.

On the Eiffel Tower in Paris, which is an admirable site for such experiments, there was registered during the summer of 1889, three times more wind than at the Paris Meteorological Office, 940 feet lower and a quarter of a mile distant; but this ratio was not constant for the different hours of the day, as it varied from five in the early morning to two at noon.

THE DIURNAL WIND VELOCITY AT DENVER AND PIKE'S PEAK.

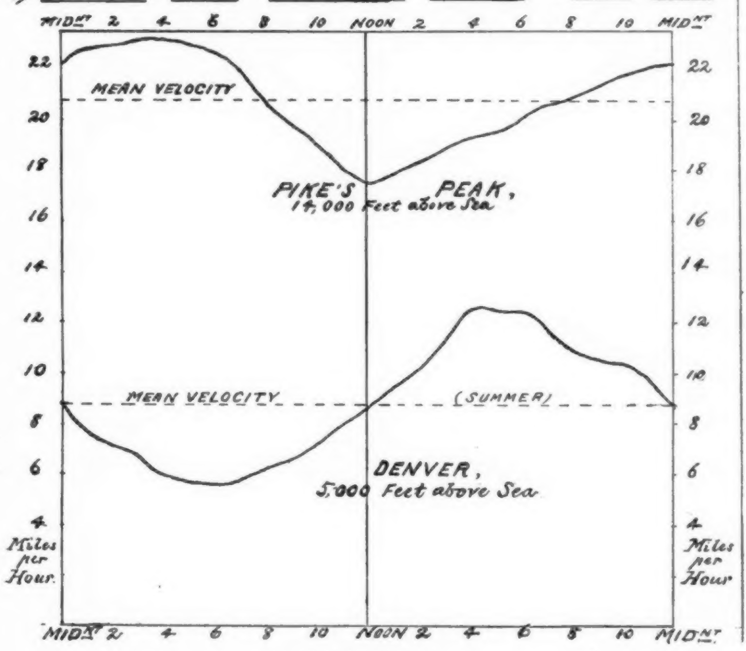


FIGURE II.

These facts are shown graphically in the accompanying series of diagrams, in which the vertical lines (or abscissae) represent the wind's velocity in miles per hour, and the horizontal lines (or ordinates) the hours from midnight to midnight. If, therefore,

the velocity at each of these hours be connected by a curve, as has been drawn for a pair of stations in each diagram, we shall have a representation of the diurnal velocity of the wind.

Regarding Boston and Blue Hill, it will be seen that the mean velocity at Blue Hill (indicated by a dotted line) is more than half again as much as at Boston (indicated in the same way), and that the highest and lowest velocities at the latter station between which there is a difference of over three miles, occur slightly earlier than at Blue Hill, though at both they take place in the morning and afternoon respectively.

Looking now at the diagram for Paris, we see that the variation at the lower station, that of the Central Office, is nearly the same as for Boston, although the extreme velocities occur a little earlier in the day. But on the Eiffel Tower the trend of the curve is very different, the lowest velocity there happening somewhat before noon (when the difference between the velocity near the ground is least) and the highest velocity just before midnight (when the excess above the velocity at the lower station is greatest). As already stated, the mean velocity on the tower is three times that near the ground.

We will next consider Denver and Pike's Peak. Though Denver is high above the sea, yet being situated upon a plateau, its diurnal wind period does not differ much from the low stations which we have examined. On Pike's Peak, however, the highest velocity occurs between 4 and 4 A. M., and the lowest velocity at noon, thus almost completely reversing the low-level condition, as the minimum difference is found at 4 P. M. and the maximum at 4 A. M.

It is interesting that the explanation of the day-time increase of surface-wind was first given by one of our most distinguished American meteorologists, Espy, who in his *Philosophy of Storms*, published in 1840, says: "The commencement of upmoving columns in the morning will be attended with an increase of wind, and its force will increase with the increasing columns; both keeping pace with the increasing temperature. This increase of wind is produced partly by the rush of air on all sides at the surface of the earth towards the centre of the ascending columns, producing fitful breezes, and partly by the depression of air all around the ascending columns, bringing down with it the motion which it has above, which is known to be greater than that which the air has in contact with the asperities of the earth's surface." Just the reverse alternation might have been

predicted in the velocity of the upper winds, but it was not thought of until Hellmann, of Berlin, found it in 1875 in studying the Mount Washington observations. Since then it has been demonstrated to exist on the various European mountains which possess anemometers, such as the Obir, Säntis and Ben Nevis, and the theory of the inversion was restated by the German meteorologist Köppen, who explained that it was produced by the vertical interchange of air by heating. At night, when local convectional currents are absent, the lower air is mostly controlled by the friction of the ground, so that its velocity is checked, while the upper currents which are caused by seasonal and not diurnal differences of temperature, and which move faster owing to less friction, continue their course unchecked. During the day the expansion of the lower strata by solar action, causes an intermixture of air to take place between the upper and lower layers, by which the velocity of the lower layer is increased by the greater velocity which the descending air brings into it from above, while the upper layers have their velocities decreased by the smaller velocities which the ascending lower air, retarded by the asperities of the earth's surface, possesses. Thus, while the mean velocity of the atmosphere may remain the same, the difference between the velocity above and below should undergo a diurnal period, the minimum difference occurring somewhat after midday. As a fact, the mean hourly wind velocity for the day on Pike's Peak is nearly the opposite of the mean hourly temperature, while at low levels it is nearly coincident with it.

The inversion of the wind's diurnal period has until recently been assumed to be characteristic of high mountains, and a new and surprising fact was that the small height of the Eiffel Tower sufficed to produce an inversion. As already shown, normally this does not occur on Blue Hill, but it has been noted for two months, and during shorter periods when the pressure was high. During such periods of high pressure and strong insolation the inversion of wind velocity between day and night is probably due to the sea breeze which during the middle of the day blows in from the east and checks or reverses the prevailing west winds which, on account of the gradients favorable to them, resume their strength at night. It would appear, therefore, that the neutral plane at which the velocity during the day is the same as during the night, lies between the limits of 500 and 1,000 feet.

The gradual advance of the minimum and maximum from about 5 A. M. and 1 P. M., respectively, at Paris, to noon and 3 A. M., respectively, at Pike's Peak, is another curious phase to which, I believe, attention has not before been called.

That the wind has not only a horizontal motion but also a vertical motion, even when not affected by obstacles, has been lately shown on the Eiffel Tower by means of a meter which is only driven by winds having an upward or downward component. In a storm, with a horizontal velocity of forty-two miles an hour, the upward velocity reached seven miles per hour. Down-blowing winds are rarer and have a less velocity.

The average annual wind velocity is by no means proportional to the height of the station above the ground or above sea-level. Thus, Mount Washington has a much higher monthly wind velocity than Pike's Peak, which is more than twice as high, the wind direction and velocity at the former station being controlled by the cyclonic storm-centres, instead of by the general atmospheric circulation which gives Pike's Peak its prevailing westerly winds. For this reason this elevated station has an annual wind movement for the year not greatly exceeding that on Blue Hill, whose winds are cyclonic in character, with a westerly component much less than that on Pike's Peak. It should also be remembered that the prevailing westerly current here observed has a much less velocity than that shown by the high clouds on account of the friction of the flat mountain top.

The velocity of both the upper planetary and the lower cyclonic winds is influenced by the season, being least in summer and greatest in winter.

One of the theories to explain storm movements is that these atmospheric disturbances are carried along by the general movement of the atmosphere, as eddies on the surface of a river are borne along by the current in which they exist.

A comparison by Mr. Clayton of the means of twenty-three months of observation, at Blue Hill with the mean storm velocities for the same months showed that, while in general both the storm velocity and the general atmospheric movement was higher in winter than in summer, yet the means vary very irregularly from month to month. A comparison of the storm velocities with the cirrus velocities showed that out of eleven cases in which there was a decrease of cirrus velocity, there were eight cases in which there was a corresponding decrease of storm velocity, and out of eleven cases in which there was an increase of

cirrus velocity, there were nine cases in which there was a corresponding increase of storm velocity; that is, in seventeen cases out of twenty-two, the storm velocity changed with the cirrus velocity. A similar comparison with the surface winds at Blue Hill showed that in only twelve cases out of the twenty-two did the change of storm velocity correspond to a change in the wind velocity.

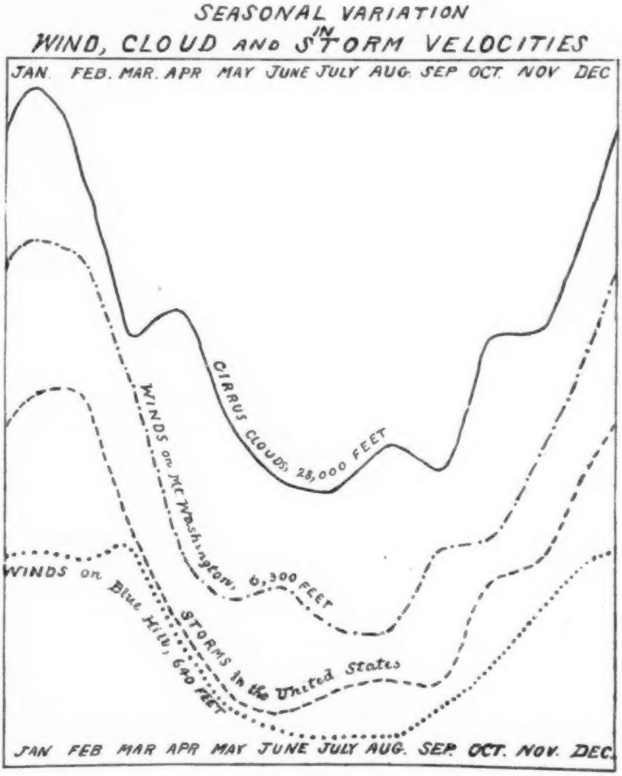


FIGURE III.

The practical inference to be drawn from this is the necessity of observing the change in the velocity (as well as in the direction) of the cirrus clouds in making weather predictions.

We will now consider some phenomena relating to the *temperature,* and the atmospheric pressure as related to it, at high altitudes. As was stated in my first lecture, the annual range of temperature generally diminishes with height, though it is greatly dependent upon the latitude and the geographical situation. Thus, the annual range of the temperature on the great plateau west of the Mississippi is nearly the same as that in the Mississippi valley itself.

From the decrease of temperature amplitude at stations situated at different heights, Hann has calculated that at an altitude of about six miles, which is that at which the cirrus clouds float, there is almost no difference of temperature between day and night, or between winter and summer. Generally the difference of temperature between the mountain heights and valleys is greatest early in the spring, when the snow has already disappeared below and the ground is strongly heated by the sun high in the sky, while on the heights all the solar energy must be employed in melting the snow.

The cause of the high pressure in summer and the low pressure in winter on elevated parts of the frigid or temperate zones, lies, as stated in my first lecture, in the drawing together of the air by the cold of winter, and its expansion by the warmth of summer. The higher the station, so much the stronger is the effect, which also depends on the annual temperature range of the air column. The change of pressure, therefore, on mountains depends on two causes, a change of pressure which is felt below, and the simultaneous change of air temperature. On high peaks, in consequence, the barometer may show quite different variations from one in the valley. For example, when the temperature falls decidedly, the barometer must fall on the mountain, even though it has remained stationary in the valley.

Together with the mean decrease of temperature with height, which has now been fairly well determined from the mountain stations, the change of temperature with height under various weather conditions, such as cyclones and anti-cyclones in winter and in summer, was put forward in 1879 by Dr. Hann, as very important for any theory of atmosphere equilibrium. In a recent memoir, Dr. Hann has answered this in a way which seems to contradict the hitherto generally accepted theory of storm generation, and this is the most important question which is now occupying the attention of meteorologists. Briefly stated,

it is as follows:—From many observations at mountain stations, Dr. Hann showed that in barometric maxima in general, up to a height of about three miles, the temperature is higher than in the barometric minima. Near the ground, the temperature in winter is lower in the maxima than in the minima, on account of the cooling of the air near the ground, chilled by radiation; but as the temperature decreases more slowly in the barometric maxima than in the minima, at a moderate height the air becomes colder in the minima than in the maxima, and the temperature excess is maintained up to the greatest heights at which we possess observations. This shows that the ascent of air in cyclones (or areas of low pressure), and thus the prime cause of them, does not exist in the excess of temperature of the air in the cyclone over that of the surrounding air, as has generally been thought. Dr. Hann supposes that cyclones are the effect of the general circulation of the atmosphere, caused by the difference of temperature between the equator and poles.

It should, perhaps, be stated that the term *cyclone* is here used in its original and technical meaning of a large atmospheric whirl, into which area of lower pressure the winds blow spirally in the direction contrary to the hands of a clock. It is accompanied by cloudy or stormy weather, while an *anti-cyclone*, an area of higher pressure, from which the winds blow spirally outward in the direction of clock hands, is accompanied by fine weather.

A graphical representation of Hann's theory indicates that in the anti-cyclone, where the pressure is higher, as shown by the bending upwards of the isobars, the temperature is also higher, as seen by the same curvature of the isotherms, except near the earth's surface, where the temperature is lower. In the cyclone, or area of low pressure, both isobars and isotherms have the same curvatures downwards, except near the ground, where the isotherm bends upwards, indicating greater heat than in the cyclone.

Professor Ferrel, the leading meteorologist of this country, has been the ablest exponent of the former theory of cyclone generation, which was admirably explained to the Lowell Institute several years ago by Professor Davis.

Professor Ferrel says that the prevailing theory of storms simply requires that the temperature of the air in general, over an area several hundred miles in diameter in the interior of a storm, shall be higher than that of the air in general around it

at the time of the occurrence of the storm, so that the heavier air around the storm shall force the internal air up, and cause an ascending current.

He thinks Hann's results do not disprove this theory for the following reasons:—

1st. Hann's results only show that in one or two storms the temperature of the air up to one or two miles was below the average of the time of year, and do not show that the air was colder within these storms than outside at the same level.

2nd. Hann's observations only extend to the height of two miles, and even if he had shown that the air was colder within the storm than outside of it, up to a height of two miles, it would not prove that the mean temperature of the air column in the storm was lower than the mean temperature of the air around the storm from the earth's surface up to the top of the storm.

3d. In storms, the precipitation of rain and snow which falls from a great altitude, cools the air next the earth's surface and thus may give the appearance of the air being colder in storms, when in reality, in the cloud region where condensation takes place, the air is much warmer than air at the same altitude elsewhere.

4th. The snow, ice, and other local causes affect the observed temperature on mountains so that the observations can not be taken as accurately representing the temperature in the free air.

It is hoped that the discussion of many thousand cirrus cloud observations by Mr. Clayton, which is now in progress at the Blue Hill Observatory, will aid in establishing the way in which the upper winds move around the cyclonic and anticyclonic areas, and so add very much to our use of cloud observations in weather prediction.

The decrease of temperature with height in the northern hemisphere has been found to average 1° for each 316 feet of ascent, but it varies greatly with local conditions and may indeed be completely reversed, as will be seen by the following examples.

The normal temperature at the summit of Blue Hill is 2° lower than that at the base, giving a decrease of 1° for each 220 feet of ascent. Inversions of temperature frequently occur, when, the temperature at the base is lower than at the summit. The inversion of Aug. 22–23, 1886, illustrated in the diagram, was the subject of an investigation by Mr. Clayton. Curve 1 shows the tracing of a thermograph at the summit of

the hill from noon of Aug. 22 to noon of Aug. 23. Curve 2 (dotted) shows the tracing of another thermograph at the base or rather on the slope of the hill, 400 feet below the summit. It is seen that the temperature was higher at the base during the day and decidedly lower at night. The temperature continued to fall at the base until sunrise of the 23d, while at the summit it rose after 11 P. M of the 22d. This inversion occurred on an unusually clear, quiet night, and is a marked example of what almost invariably takes place on such nights.

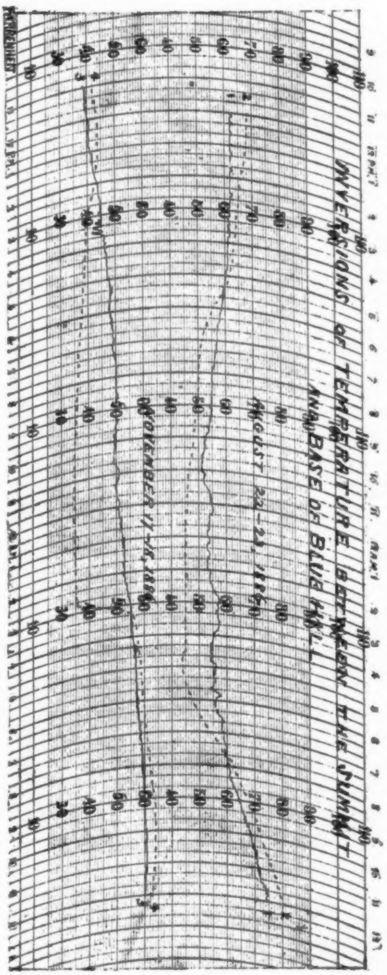


FIGURE IV.

At this time a cool dry area of relatively high barometer had overspread New England, although all around the temperature was higher. The air blowing out in every direction from this area of high pressure, evidently came from above, but its coolness would not have resulted from this, since it was cooler at the earth's surface than at points above it. This has been already shown for Blue Hill, and on Mount Washington the temperature was several degrees above normal. These facts point to two oppos-

ing actions on the air: (1) a heating effect due to compression of the air by its descent, and (2) a cooling effect due to radiation, chiefly from the earth's surface. At elevated points such as Mount Washington, where the land surface is small, the heating effect was in the ascendency, the temperature of the air was above normal and actually rose during the night. At lower stations, the cooling by radiation was in the ascendency, and the temperature of the air fell continuously during the night. This example seems to confirm Dr. Hann's observations in Europe of the increase of temperature with height in an anti-cyclone.

An inversion of another kind is illustrated in the lower pair curves 3 and 4, which are the tracings of the thermographs at the summit and at the base of the hill, respectively, from 11 A. M. of Nov. 17 to noon of Nov. 18. It is seen that the temperature at the summit rose continuously, while the temperature at the base fell from 1 P. M. of the 17th to near 3 A. M. of the 18th, when it was 20° lower than at the summit. This was caused by the not uncommon occurrence of a flow of cold northerly winds around the base, while a strong southerly wind prevailed at the summit. At 10 P. M. of the 17th the wind was blowing three miles per hour from the northwest at the Boston Signal Office, which is ten miles north of Blue Hill Observatory, and about five hundred feet lower; while on Blue Hill it was blowing at the rate of twenty-eight miles an hour from the south. Reports from other stations show that this thin cool northerly current overspread the whole of New England, and was accompanied by a dense fog. Between 3 and 4 P. M. of the 17th these two currents were fighting for the mastery at the summit of Blue Hill, and its effects are seen on the thermograph curve. During this time a cool, damp, foggy current would roll in, lasting five or ten minutes; then it would be displaced by a warmer current from the south lasting about the same interval. This alternate action lasted over half an hour, after which the southerly current remained permanently.

Whenever the free atmosphere is concerned, mountain observatories, notwithstanding their superiority otherwise, cannot replace balloons, since they never can be freed from the mountain mass, while the balloon carried by the air itself exerts, in a very much less degree, an influence on its surroundings. This and other considerations, therefore, led scientists of all nations to make ascents for investigation. It was even said that the basket of a balloon should play the part of a *cradle* to an important

section of meteorology. Among the problems, whose solution was thus attempted, was the determination of the temperature and humidity, two elements which have the greatest influence in meteorological phenomena. For a long time it was (and is still by many æronauts) thought sufficient to obtain trustworthy temperatures that a thermometer should be hung in the basket of the balloon or on the ring above it.

Then it was seen that the data depended upon the very variable conditions of sunshine, shade, and moisture, so that often with a rapid change of elevation of the balloon, the thermal change did not correspond to the thermometric readings, and it was sought to protect the instruments by making them more sensitive and withdrawing them from disturbing influences, For this purpose the thermometers and hygrometers were inclosed in a shelter or perforated box and their surfaces in contact with the air were increased, so that the above mentioned disturbances were partly neutralized but were replaced by new and more injurious ones, for since, in a freely-moving balloon, there is almost a calm, any obstacle to the free access of air to the apparatus must occasion errors. Another difficulty was to obtain a barometer sensitive enough to follow the rapid changes of height of the balloon, and even supposing accurate readings could be obtained simultaneously with the other observations, there was still the impossibility of determining the height accurately unless the temperature of the air column was known. Under these conditions were made the most famous balloon ascents of the century, such as that of Gay-Lussac in 1804, who reached a height of 23,000 feet, Barral and Bixio in 1850, and Welsh in 1852, who both attained nearly the same altitude. The English æronaut, Glaisher, in 1862, ascended to the greatest height ever attained, viz., 29,000 feet, afterwards nearly equalled by the French æronauts Crocé-Spinelli, Sivel and Tissandier in 1875, when the former perished. But largely owing to the difficulties mentioned, these high ascents were productive of little good to meteorology, and of late years they have not been repeated. Among the remarkable temperatures observed was that by Barral and Bixio in July 1850, of — 40° F. at a height of 23,000 feet, and open to still more doubt is the extraordinarily high temperature of over 80° F. recorded by the American æronaut Wise in July 1874 at a height of 6,000 feet.

The observations conducted by Glaisher during his numerous ascents are probably the most trustworthy on account of the

instruments used and the methods of observation. The chief result obtained by Glaisher was to show that the decrement of temperature diminishes with elevation, a fact which has not been confirmed by the observations on mountains. A series of observations by Glaisher in a captive balloon up to a height of 1,000 feet during the summer of 1869 showed that the vertical distribution of temperature has a diurnal range and varies also with clear and cloudy weather.

Since the recommendations of the Roman Congress were made, as already stated, little has been done either with captive or free balloons for meteorological purposes, though I might perhaps mention some balloon ascents up to moderate altitudes which have been made under the auspices of the United States Signal Service. Of late the Germans have utilized military balloons for meteorological work, and Dr. Assmann of Berlin, has recently devised an aspiration psychrometer for ascertaining the true temperature and humidity of the air. Such an apparatus was long ago tried by Welsh and Glaisher, but it was not in a practical form for balloon observations and was soon abandoned. The new instrument seems to solve the question of exposure in a balloon by insuring both ventilation and protection from insolation and more accurate measurements of temperature and humidity will doubtless result from its use. I shall illustrate graphically the difficulty of exposing thermometers in a balloon by giving the results of two balloon ascents which I made in Paris in November, 1889. As these ascents are among the few in which self recording instruments have been employed, they have a certain interest. These instruments were the barograph, thermograph and hygrograph of Richard *frères* which automatically recorded continuously the variation in the atmospheric pressure, air temperature and humidity.

The diagram is a copy of the record sheets of these instruments which were hung to the ring of my balloon above the car or basket. The lower traces are those of the barograph which show the height in meters, assuming the pressure and temperature decrease to be constant. The middle traces are from the thermograph, showing the variations in temperature. The dotted lines below are made up from readings of a sling thermometer, both being plotted on a Centigrade scale. A sling thermometer is simply an ordinary thermometer tied to a string and swung in a circle, and such an observation, even though made in the sun, gives a very good approxim-

ation to the shade temperature, and avoids all trouble about the free circulation of the air around the thermometer. The thermograph was shielded as much as possible from the sun, which was not easy as the balloon was constantly turning on

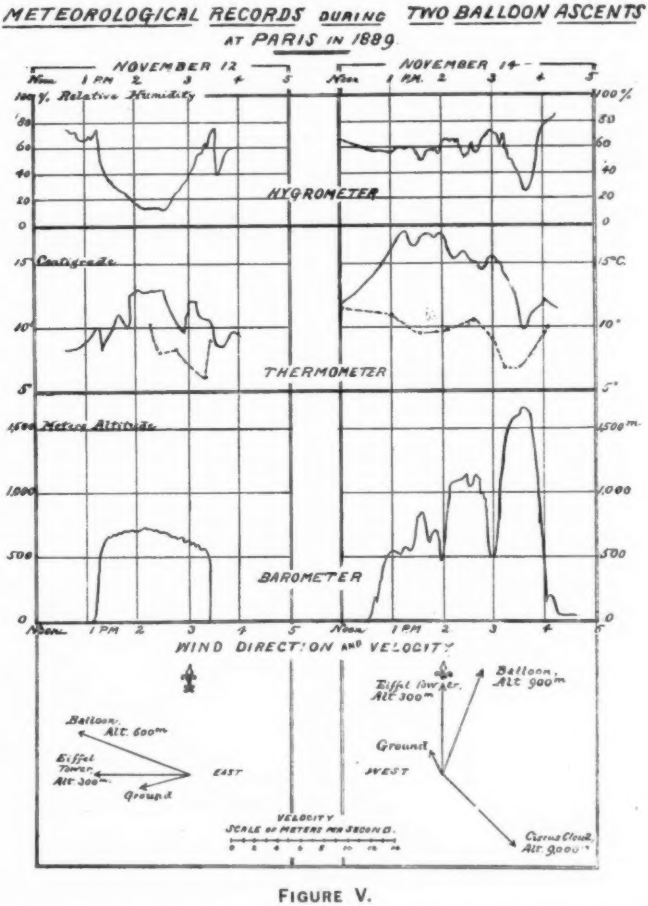


FIGURE V.

its axis and exposing another side to the sun so that the gas bag itself became heated. The air in the car was also stagnant, some of it probably having been brought up from near the

earth's surface like water in a well bucket. The divergence of the two curves shows the undue heating of the thermograph causing it to record 8° C., or over 14° F. too high in my second voyage. The upper traces are the relative humidity in per cent. of saturation obtained from the hair hygrograph whose indications were controlled by means of a dew-point apparatus. In general, at the earth's surface the temperature and relative humidity are the reverse of one another, that is to say when one rises the other falls, and *vice versa*, but in ascending to high altitudes both the absolute humidity and the temperature are low. This is seen at the highest point reached in the ascent of Nov. 14—about one mile—when the temperature fell to 44° F. and the relative humidity to 25 per cent. The low humidity (12 per cent.) at the highest point reached on Nov. 12 may also be noted.

For the reason which causes the lack of ventilation to the thermometers, a free balloon is one of the best of anemometers since it has the motion of the air in which it floats, so by noting the time of starting and landing and the places passed over, a good knowledge of the wind's direction and velocity is obtained. Thus in the voyage of Nov. 12, the ground was left at 1:12 and a landing effected at 3:25, 45 miles distant, showing a velocity of 22 miles an hour. The course was NNW., and the average height of the balloon was about 600 meters, or less than half a mile. At the same time on the Eiffel Tower, at less than half the height, the wind blew from the west with a velocity of 18 miles per hour. In the voyage of Nov. 14, the height was very variable, averaging 900 meters, or 0.6 mile, the distance traveled in a NNE. direction being 71 miles in 3½ hours, giving a speed of 20 miles an hour. The wind meanwhile at the level of the Eiffel Tower blew with an average velocity of 16 miles per hour from the south. In both cases the upper winds veered with respect to the lower, that is, they were deflected towards the right hand, and this was the case from the earth's surface up, as shown by the records of the meteorological stations near Paris, where the wind direction differed from that on the Tower.

These facts are recorded in the lower portion of the diagram where the arrows fly with the wind, and in length are proportional to its velocity expressed in meters per second. This diagram shows that change in direction which would be expected from an inspection of the synoptic weather maps of Europe on

these days. On both the 12th and 14th of November the weather in France was controlled by an area of high pressure in the west, from which the surface winds blew outward. On Nov. 14 the surface winds were also slightly influenced by an area of low pressure approaching the British Isles, causing southerly winds at the ground. The upper winds tended to circulate around the area of high pressure in the west, as shown by the direction of the cirrus clouds on Nov. 14, in accordance with the normal circulation. The effect of the ground in checking the motion of the lower winds is seen in the increased length of the arrows representing the higher currents. The velocity of the upper winds, which carried the cirrus cloud, is not known, but it was undoubtedly much greater than the velocity of the balloon.

But for regular meteorological observations at high altitudes in all weathers we must return to our mountain stations and with the extension of our knowledge of the conditions prevailing in the higher atmosphere it will be possible to employ more than formerly the observations of our summit stations for weather predictions. Hitherto there have been but a few summit stations and it would evidently be absurd to expect the problem of weather predictions to be solved all at once from their observations. Only a full understanding of the connection of all atmospheric phenomena will enable this to be done and the high-level stations will aid greatly in acquiring the knowledge. At present our forecasts are based upon weather maps which show the meteorological conditions prevailing simultaneously over a large extent of country but generally at or near the general level of the sea or land. It is now recognized that a knowledge of the vertical variations which take place in the atmosphere is of the utmost importance and this can be ascertained only by regular observations at stations which, while near together, differ in height as much as possible. The advantage of such a pair of stations for weather predictions has been practically demonstrated on Ben Nevis where it has been observed that a more rapid decrease of temperature than the normal between the top and bottom of the mountain was generally followed by a storm.

For the study of the conditions prevailing at high altitudes, as Teisserenc de Bort has stated, it is not necessary to have complete meteorological observatories on the mountain summits with a staff of observers making frequent direct observations, for,

owing to the progress which has been realized in self-recording instruments, it is now possible to obtain accurate results without the aid of an observer, thus largely reducing the expense. These observations must be limited to the most important elements, such as the wind, the atmospheric pressure, the temperature and, perhaps the relative humidity and the rain and snow fall, though the latter cannot be accurately determined on mountains.

At the more exposed stations probably only the temperature and atmospheric pressure could be recorded. For these elements there are self-recording instruments which will operate for two weeks without attention, without large errors. The present system of mountain observatories can therefore be completed by establishing other secondary stations provided with self-registers whose sheets would be changed each week or two, and having also direct-reading instruments to serve as standards. The stations would cost at the most $1,200 to establish and $120 a year to maintain, and would permit charts of the weather conditions at high levels to be drawn, thus marking a distinct advance in the study of the general movements and, consequently, in meteorology as a whole and its practical application to weather prediction.

An example of such an economical mountain observatory already exists on the Semnoz in the Alps of Savoy. This mountain rises more than 4,000 feet above the Lake of Annecy and on the top is a hotel. The meteorological observatory, however, is an isolated tower covered with shingles. The self-recording and direct-reading instruments, with the exception of the rain-gauges, are placed in or outside the second story of the tower to which entrance is had by a ladder. This serves the double purpose of protecting the instruments from tourists during the summer and raising them above the snow-level in winter, the rain-gauge being also elevated. Once a week the observer, who in summer is the inn keeper but in winter comes up the mountain, winds the clocks and changes the sheets of the self-recording instruments, at the same time making a reading of the standard instruments. This station is maintained by the French Meteorological Office at a cost of about $50 per annum.

M. Vallot's cabin on Mont Blanc (see this JOURNAL, January, 1891) is another example of such a station in a more inaccessible situation, which is to be maintained only in summer. In the

Eastern United States there are many peaks suitable for such observatories. Among them are Mount Mitchell in North Carolina, the highest peak of the Appalachian range, and Mount Marcy in in the Adirondacks. A station on one of the sharp summits of the White Mountains, which perhaps could be operated in summer only, would explain how far the severe conditions experienced on Mt. Washington are local or abnormal. These stations could not give data for the current weather forecasts, but their records would serve for subsequent study and would help to answer some of the questions I have already indicated, which we, as a practical people must first do, before we can arrive at our goal of successful weather prediction from a combination of expensive low-level and high-level stations reporting by telegraph to a central office.

THE ASPIRATION PSYCHROMETER AND ITS USE IN BALLOONS.*

By Dr. R. Assmann, of Berlin.

Among those problems whose solution is possible by means of balloons, the determination of the temperature and humidity distribution in the atmosphere, holds first place. We know in general that the temperature decreases with elevation above the earth's surface, so that the aqueous vapor contained in the high atmospheric strata is less than that in those strata nearer the earth, but our knowledge of this diminution under various weather conditions is extremely incomplete. The conditions of equilibrium of the atmosphere are so dependent upon the two elements, temperature and humidity, that a general advance in atmospheric physics appears impossible without such accurate knowledge. Soon after the invention of balloons, they were used for meteorological observations, but little was accomplished by a simple ascent into the high atmosphere, for it was necessary to make quantitative measurements, and to do this, suitable methods and apparatus were needed. The practical English first proposed the proper means to avoid the chief disturbances caused by poor exposure when Welsh, in 1853, used a thermometer with artificial exchange of air by aspiration. But, although the cleverest and most renowned of aeronauts, James Glaisher, repeatedly employed Welsh's apparatus, he did not

*Translated and abridged from *Die Zeitschrift fur Luftschiffahrt.*

succeed in giving it such a form as to fully adapt it to balloon use. Ignorant of these experiments of Welsh and Glaisher, the author, in the course of some experiments, had the idea of enclosing the thermometer in a polished metal case, and inducing a continuous air current. The polished envelope was to reflect a portion of the impinging heat rays, and by the continual renewal of the air in its normal condition, in so great quantity and with so great velocity about the thermometer bulbs, the single particles will not have time to be warmed by the slightly higher temperature of the envelope. Thus originated the aspiration thermometer, and from similar considerations, the aspiration psychrometer, in which another thermometer, with its bulb covered with muslin, kept wet in the usual way, was similarly exposed. After trying many experimental instruments, the author has succeeded in giving to the apparatus a form in which all demands are fully satisfied.

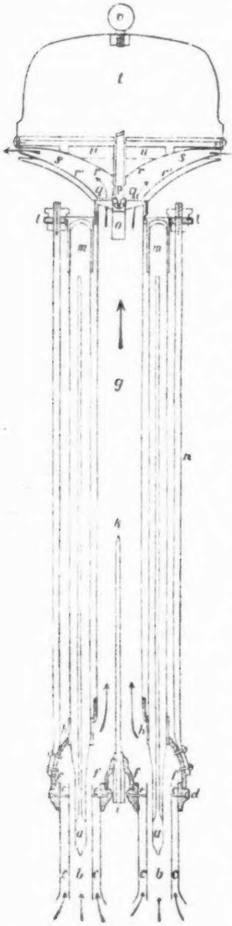


FIGURE I.

The apparatus in its present definitive form is the following: Two verified thermometers, divided to 1-5°C. with cylindrical bulbs 4 mm. in diameter and 12 mm. long (*a* in Fig. 1) are enclosed at their lower ends in open cylindrical tubes, 1 cm. in diameter and 5 cm. in height *b*, so that the bulbs are somewhat above the middle of the tubes, but exactly in its axis. This tube *b* is surrounded by a second, wider one *c*, which has a diameter of 1.75 cm., and a length of 4.5 cm., and is funnel shaped, so that it is 2.5 cm. in diameter at the bottom. The two envelopes, *b* and *c*, have a thickness of 0.5 mm., and are made of brass, nickeled and highly polished, outside and inside. The inner tube *b* is fastened to the outer one *c*, by means

of small metallic screws *e;* the outer one is screwed into the ivory ring *d.* Since the outer tube is shorter than the inner, and extends 2 mm. below, there is no metallic connection between the two tubes. The ivory rings *d,* are screwed into the two nickled brass castings *f,* 2 mm. thick, which form two tubes of 2.1 cm., connecting with a tube of 2 cm., diameter. Vertically above the inner envelope *b,* both branches are perforated for the thermometers, which are fitted by metallic rings *h* into the apertures. On the middle portion of *f* the brass tube *g,* 21 cm. long, is fastened. Between the two branches of the casting *f,* a narrow tube, 2 mm. in diameter, is screwed, which is widened at *i,* and contracted above at *k* into a fine point. The central tube *g* carries at its upper end two arms, projecting 2 cm. at *l,* which have holes to receive the metal heads of the thermometers *m.* To insure the thermometer being parallel to the central tube, there are rods fastening the whole instrument together, and the nuts securing the heads of the thermometer *m,* serve to prevent the latter from falling out. In the interior of the central tube *g,* there is a bearing *o* held by small supports in which an arbor *p* connected to clock-work rests. Around this axis rotates the metallic aspirator vanes *r* and *r′,* which are convex downward, have a diameter of 8.4 cm, are distant from each other 1 cm. in the middle, and 3 mm. at the circumference, and are connected by four correspondingly-shaped ribs *s* with one another. These ribs are so arranged that they enclose the air flowing out centrifugally between the disks. The lower disk *r* is cut off, forming a ring whose edge is close to the upper edge of the center tube *g,* so that both rims enclose the smallest possible space. On an enlargement of the center tube, a metallic cap *t* rests, enclosing the clock-work and aspirator, and having at its lower edge apertures *u,* 5 mm. wide all around. On the top of the cap a knob *v,* which is clamped by the jaws on an arm 30 cm. long, forms a ball and socket joint, by which the whole aparatus can be suspended from any object into which the arm is screwed. All the parts are covered with polished nickel. Fig. 2 shows an exterior view of the instrument.

Let us now look at the working of the apparatus. When the two pairs of disks are set in motion around the central axis, the air between them is forced out. To supply this, air is drawn through the opening in the disk (*q,* Fig. 1) from the middle tube *g* and past the two thermometer bulbs through the double

casing *b* and *c* of the two branches, as shown by the arrows. According to experiments with a disk of 8.4 cm. diameter, a velocity of fifteen turns per second gives a sufficient draught of air through the apparatus which can be maintained for eleven minutes. In order to measure the amount of air drawn in, the following method was used: The tubes were connected hermetically with a glass cylinder of five liters capacity, whose end was dipped in soap suds, and after the aspirator was put in motion, the velocity with which the soap film was drawn through the cylinder was noted to be five seconds, which established the minimum volume of air passing through the apparatus to be one liter per second.

By the direct rays of the sun, the outer envelope is heated above the temperature of the air, while the inner tube, having nearly this temperature can communicate very little heat to the stream of air. In order to show the amount of heating, the outer tube was smeared with fat whose melting point corresponded to a definite temperature. Under the intense insolation on high mountains it was found that the outer tube never rose more than 3° C. above the air temperature when the aspirator was in action. To ascertain whether a difference of 3° is of importance, two aspiration thermometers were exposed in a room and a funnel filled with hot water was arranged to surround the tube of one thermometer. The surprising fact appeared that this tube might be raised 30° C. above the air temperature without influencing that of the enclosed thermometer 0.1°. From these considerations it follows that the thermometers are fully protected from the most intense insolation, while the wetting of the thermometers by rain is entirely avoided by the double casing.

All temperatures hitherto obtained in ascending and descending balloons show that thermometers cannot follow the rapid changes of temperature. Even in ascents where the changes of temperature are small, the temperatures obtained in rising are considerably higher than those obtained in the descent at the same altitude, whenever the change of height is rapid. The thermometer cannot follow the sudden changes of temperature but records in the ascent the higher temperature of the lower strata, and in the descent the lower temperature of the higher strata, after a sufficiently long stop in any layer has brought the thermometer into equilibrium with the air temperature. This apparatus insures by the continual renewal of the air in connec-

tion with extremely small thermometer bulbs, a considerable increase of sensitiveness, if care be taken that it keeps so far outside the balloon basket that air brought up in, or influenced by it cannot affect the thermometer.

According to the experiments of Dr. Sprung, the aspiration psychrometer requires another constant in the usual formula $f = f' - A\,(t - t')\frac{b}{755}$ in which t is the temperature of the dry bulb, t' that of the wet bulb, f' the maximum vapor tension at the temperature t', F the actual vapor tension to be determined, b the height of the barometer, and A a constant, which instead of 0.6 should be 0.5 with this instrument, because the velocity of the air current is greater than with the ordinary psychrometer.

For balloon use the instrument undergoes certain important modifications, since in ascents the cloud strata cause great variations in humidity in a very short time, so that the muslin covering of the wet-bulb, becoming dry by evaporation must be wet when it takes the temperature of the water. To avoid this, there are two wet-bulb thermometers which are read alternately. For this purpose, the apparatus instead of the two branch tubes shown in Figs. 1 and 2, has three, the central one like the others enclosing a thermometer. Two of the thermometer bulbs are covered with muslin, which is wet before the commencement of the observation, and so long as the thermometers give the same temperature, either may be used. After some time one of the bulbs is wet, and generally its temperature will be altered by the water, but after a time both thermometers will read alike and the observation can be proceeded with. For wetting the bulbs a useful device is a rubber ball attached to a glass tube a little larger than the thermometer bulb. The ball is filled with distilled water and is closed by a spring clasp, so that it can be carried in the pocket and shielded from frost.

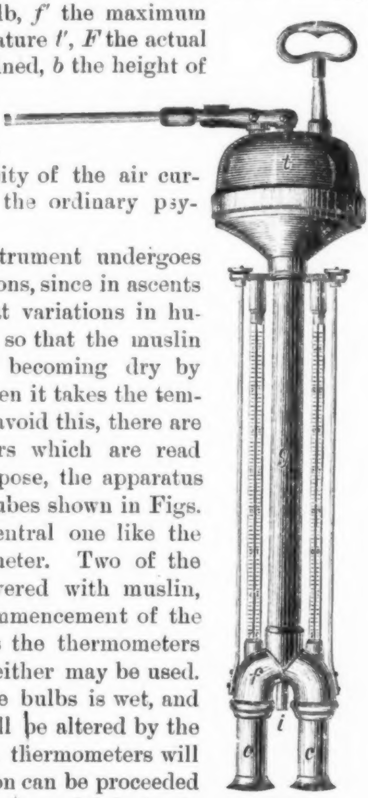


FIGURE II.

There remains to describe the use of the small central tube *i*, shown in Fig. 1. By means of a rubber ball worked by hand this delivers a strong stream of air into the central tube through the small opening *k*. This, acting like an injector carries the air in the tube with it and thereby induces a current past the thermometer bulbs. The elastic ball is enclosed in a net so that the blast, and consequent aspiration, is made continuous. With this arrangement alone a current of 2.6 metres per second is induced past the thermometer bulbs; with clockwork aspirator and hand injector together a velocity of three metres per second is obtained. In balloons the injector is only intended to be used in case of an accident to the clock-work.

The instrument is made by R. Fuess of Berlin, and fully tested is sold for 160 M. or $40. Employed in balloons, it should give much more accurate determinations of temperature and humidity and perhaps effect a notable change in the data upon which rest our theories of thermodynamics. The aspirator may be driven by a small electric-motor, instead of by clockwork, during eight or ten hours and, according to the scheme of Herr von Sigsfeld, may be arranged to give a continuous photographic record of the temperature changes in the upper air. The German Society for the Promotion of Aeronautics is constructing a small captive balloon which will carry up, on as many days as possible, such a self-registering apparatus, in order that information may be obtained which will help to solve questions of importance to meteorology as well as to æronautics.

THE BERGEN POINT TORNADO.*

By William A. Eddy.

The tornado was first observed at Bergen Point, the western extremity of a peninsula which extends along opposite the north shore of Staten Island, and on a narrow arm of New York Bay called the Kill von Kull. The tornado track was about nine miles southwest of New York City. At 5 P. M., on June 16, 1891, a dark hazy cloud appeared in the southwest, and at the same time another lighter in texture, because more distant, appeared in the northwest. I was standing on a high elevated railroad stairway in Brooklyn, near Fulton Ferry, about ten

* Exclusively for first publication in the American Meteorological Journal.

miles away from the tornado track in almost a direct line to the northeast. I was looking directly southwest across New York Bay toward the Kill von Kull, where a tornado was then in operation. The cloud was so far away that it seemed hazy and not particularly black. The usual tornado movement of smoky clouds in the southwest and heavy, dark clouds in the northwest concentrating with a circular movement upon the tornado funnel were not seen by me because I was at so great a distance. Nor were such phenomena observed at Bergen Point owing to the obscuration caused by heavy rain. A closer examination of the distant clouds revealed a peculiarity which I have before noticed when collecting tornado data for the Signal Service—that the scud clouds of lighter tinge seemed to fly very low or near the surface of the earth. But after the scud clouds passed, the darkness at Bergen Point was described as like a swiftly moving shadow obscured by the rain. An ordinary thunder cloud shows the lighter shade of the rain mist reaching to the ground below the torn, dark, low, running clouds that precede it, but the Bergen Point tornado and other instances make it clear that the tornado cloud usually shows a darkness reaching to the ground. Dark smokiness is seen instead of the lighter shade of the rain mist. In the present instance the heavy rain that preceded the crash concealed the shape of the tornado cloud. But the effect at Bergen Point was that of a rapidly moving intense darkness estimated at La Tourette House as reaching more that half way across the water to the Staten Island shore. Careful inquiry developed the fact that this moving blackness seemed less in extent at the surface of the water than in the upper air. It seems probable that this vague shape, without definiteness owing to the heavy rain, might have appeared under more favorable or rainless conditions as a funnel-shaped cloud with a hard outline. First came a thunder storm and severe lightning at 5 P. M., and then there was a lull followed by such a swiftly approaching blackness that some people fled to their cellars. It was the ordinary thunder storm that concealed the tornado funnel and gave the sky the lighter shade. Hail stones about the size of marbles are reported as both preceding and following the stroke of the tornado, which came and went in an instant. The temperature before the tornado as noted by Mr. R. J. D. Mackie was 89°. At 7 P. M., I noted a temperature of 72° on the piazza of La Tourette House. The shore temperature, as given by Mr. Mackie, was

modified by the coolness from the water. He reports an immediate fall of 10° after the storm, and Sergeant E. B. Dunn reports a fall of 16° at New York City at the same hour, the temperature declining from 91° to 75°. The temperature at 6:50 P. M. at the surface within 2,000 feet of the track was 88° on the night preceding the tornado. A self-registering thermometer carried to a height of about 1,500 feet on a kite string registered 83° minimum by 7:30 P. M., the surface temperature being 84°. The wind was strong from the southwest and increased so rapidly in velocity that the kite was repeatedly forced downward owing to want of tail. Sergeant Dunn reports at the New York office an increased average hourly wind velocity of from 13 to 18 miles an hour and a maximum velocity of 20 miles an hour. Nothing lower than 82° was brought down from the upper air. The surface temperature remained fixed at 84° until 9:30 P. M.

Heavy rain, hail, and much lightning continued for about ten minutes after the crash came and more or less light rain continued until 7 P. M. The general testimony is that no roar was heard in advance of the tornado. This was a peculiarity doubtless due to the prevalent activity of the lightning and the crashing of the thunder. The region visited is not over half a mile from the incessant rumbling of heavy trains of cars moving at high speed, a condition causing inattention to any distant roaring noise. Mr. Mackie, whose house occupies a somewhat sheltered position very close to the tornado track, says, however, that he heard a very marked roar.

The damage might have been very much greater but for the evident fact that most of the tornado's destructive force was exerted upon the waters of the Kill von Kull, which is somewhat less than half a mile in width and four miles in length, trending generally from southwest to northeast, as shown by the map. The progressive direction of the tornado path was noteworthy because it was along a line from west to east, with only a slight northward movement. The length of the track seemed to be about two miles, and its width not demonstrable, because its southward line was along the water, its destructive effect apparently not seriously affecting the Staten Island shore. On the Bergen Point shore the tornado wavered along a serpentine course, occasionally impinging upon the shore, as evinced by trees thrown northeast, north, and northwest, indicating that the motion of the wind was circular and against the direction

taken by the hands of a clock. The trees at the beginning of the tornado track and along the first mile of its course were most of them prostrated to the northwest, while toward the close of the track or along the second mile of the course, they were nearly all prostrated to the northeast. The southwest or south side of a tree, high up from the ground would reveal the stumps of large branches that had been split away, while thin perpendicular branches would be spared. This is, however, accounted for according to simple mechanical principles. Branches that project toward the wind were braced and could not be readily swept backward, while thin branches bent out of the way and were not so easily broken. One isolated tree, far up a side street away from the tornado track, was broken and bent backward toward the northwest, while only one of its branches was turned around so far that it resembled the twisted and stringy strands of a rope.

Mr. Henry D. Jennings, whose house was defaced by flying missiles, says that the branches of trees writhed and intertwined as if subjected to tremendous suction from above. He observed that the branches were not so much bent backward as twisted round each other. The wind is described by many witnesses as coming from all sides at once.

The tornado seemed to dart forth lanes of powerful wind force northward for a distance of half a mile, occasionally tearing off large branches, but sparing the outer fringe of smaller branches, giving the stricken trees a peculiarly hollow, open effect. The manifestations of destruction increased in number as the tornado track was approached, and the most marked destruction occurred at the termination of the first mile of its course. Its climax of power was reached at the old Story mansion facing the shore. The tornado did not quite reach the ground, otherwise the house would have been demolished, but as it was, huge trees two or three feet in diameter were torn up, leaving large gaping holes in the lawn, and the street in front of the house was made impassable by a number of large fallen trees. No one was killed, but a large tree was blown northward against the house fracturing its cornice. Another immense tree was thrown against the wide piazza shattering it with a glancing blow. Much slighter trees near by were not injured. The total damage along the shore was about $6,000, and this is a low estimate.

The schooner Cynthia Jane, Captain Peter Mullen, was

blown against the Bergen Point shore so hard that her timbers were sprung, requiring the use of a steam pump to keep her afloat, her bowsprit extending over the land. Her mainmast and foretopmast were blown clear away from her into the water, only a piece of the top of one of the masts remaining in the rigging. The next object that suffered was Brady's storage house, which had its roof with all its tin and some heavy timbers blown a distance of about 300 feet to the northeast, where the roof timbers and tin roofing (rolled up) struck against the house of Mr. Henry D. Jennings, smashing his second story windows, breaking down his ceilings and mouldings, bruising and fracturing the outer woodwork of his house. Part of the brick wall and bricks from the storage house were carried along with the roof, including a heavy chimney capstone weighing about 150 pounds which was blown about 300 feet. This long flight of so heavy an object may have been caused by the flying tin roof which might have lifted the heavy stone over part of the distance. Immediately back of La Tourette House, some trees twisted off half way up from the ground, were dropped in the yard. No trees like them could be found anywhere near by, and it was not known whence they came. They had doubtless been carried on with the whirling vortex of the tornado funnel and probably worked their way out of the top of the funnel and descended. Another striking manifestation of force was shown upon some trees that slanted southward over the water of the Kill von Kull. These trees were uprooted and thrown to the northward, taking a prostrate position dire tly opposite from the direction in which they had been lean ng. Upright trees near by, though of much slighter structure, v ere spared. This shows great lifting force.

The tornado seemed to lift as well as to pinch in and shatter trees and their branches. It also manifested a local twis.ing power as if small whirlwinds a foot in diameter formed w·.hin the main whirl and exerted fearful gyratory force.

The evidence in this case is very strong that when a tornado funnel does not quite reach the earth, minor whirlwinds, from one to thirty feet in diameter, are scattered along below the funnel, destroying special trees and branches. My personal examination of the tornado tracks at Camden, New Jersey; Westwood, New Jersey; New Hartford, Conn.; Chemung, Illinois; Jamestown, Ohio, and Brooklyn, New York, has disclosed the fact that when the tornado adheres to the

ground the special demolitions of trees and parts of houses are replaced by clean-cut, thorough destruction, until the funnel rises, when innumerable little destructive whirlwinds begin to scatter for a considerable distance on each side of the track above which the funnel is passing. If the funnel is very high above the ground the rending force is of course much lessened.

THE HOT WINDS OF CALIFORNIA.

By John P. Finley, Lieut. U. S. Army.

The "dry season" of California is not altogether devoid of atmospheric conditions unfavorable to plant growth and the curing of crops. Advantage is judicially taken by the farmer and horticulturist of the state's diversified climate, and every effort is made to accommodate the adaptability of plants and trees to the peculiarities of atmospheric surroundings. But the early rains of summer seriously interfere with the berry and hay crops, and the early rains of autumn with the making of raisins. These rains are dreaded much more than frost, in spite of the fact that they are beneficial to grain and pasture lands. There is no atmospheric condition, however, which creates more general alarm and anxiety than the occurrence of the "hot northers" of California. Under their influence all forms of animal and plant life suffer, and every branch of industry is affected. Recognizing the importance of this subject and the fact that little or no attention had been given it I determined to afford the people of the state the benefit of such study as my limited time will allow. The investigation has proceeded by cartographical means and a series of over forty charts has been prepared, from which the following results have been obtained.

OBSERVED CONDITIONS.

(1) The period during which "hot northers" are likely to occur embraces the months of May to September, inclusive. They have been occasionally experienced in October, but are confined in that month to Southern California.

(2) The most severe and destructive hot waves have occurred in June, August and September. The most notable are those of June 22nd, 1859, when the thermometer ranged from 100° to 118° in the shade, and great suffering was experienced by men

and animals. On June 10th, 1877, the thermometer ranged from 100° to 122°. It was at this time that the highest temperature (112°) ever recorded at Los Angeles occurred. On September 21st, 1885, the temperature ranged from 100° to 112°; on October 21st, 1890, 90° to 100°; August 24th, 1888, 100° to 116°.

(3) "Hot northers" always develop under the influence of an anti-cyclone (those of May to September), when the High is central in Washington, and those of October when the High is central in Southern Idaho and Northern Nevada. The maximum pressure ranges from 30.10 to 30.40 inches.

(4) The position of the Low (area of lowest pressure) is a very important factor. When it is located in southeastern California to Arizona, the hot wave is confined to Northern California. When it shifts to the southwest coast of California, or to Lower California, then the hot wave includes Southern California. The minimum pressure ranges from 29.90 to 29.70 inches.

(5) With a hot wave in Northern California the isobar of 30.00 passes through the northern portion of Northern California, and thence southeastward through Southern Utah. With a hot wave in Southern California, the isobar of 30.10 passes through Northern California and thence southeast through Central Arizona. The highest gradient is then along an east and west line from Central Arizona to the Pacific.

(6) With a hot wave in Northern California the winds are northerly throughout the entire region from British Columbia southward to parallel 36 degrees north, and west of the 110th meridian. South of this parallel they are westerly. When the hot wave includes Southern California the winds become northerly throughout California, Nevada, and easterly in Arizona, changing to variable in Oregon and Washington. In both cases the force is generally light to fresh (1 to 14 miles per hour). Occasionally the force becomes brisk to high in the valleys and sand storms occur on the deserts.

(7) During the prevalence of "hot northers" all stations in California, Nevada and Arizona, report entire absence of clouds and extremely low humidity.

(8) When the snow-fall has been very heavy during the winter severe hot waves do not occur the following summer and autumn. Moderate ones may develop, but they are confined to autumn. This was notably the case in 1890, following the

heavy snow of the winter of 1889–90. The light snow of the winter of 1878–79 was followed by the "hot northers" of the summer of 1879. The hot waves of 1877 followed the light snows of 1876–77.

(9) "Hot northers" usually continue not less than three days, and may last a week or ten days. The one of June, 1859, was reported to have continued nearly 15 days, and the one of June, 1877, about one week. The maximum temperature rarely holds for more than one day at any locality, although a temperature exceeding 100° may continue about one week.

(10) The movement of air southward in a hot wave is general over a large territory, and appears to be independent of mountain ranges and valleys. The highest and lowest stations report the same general direction. The energy of the anti-cyclone must be sufficient to affect a large territory and entirely change the course of atmospheric circulation therein and maintain the new movement.

(11) Hardly a season passes without hot waves of more or less intensity, depending upon the development of marked cyclonic and anti-cyclonic circulation, with a proper relative position, and the depth of the winter snow-fall.

(12) A cyclonic state of the atmosphere is the normal condition of circulation over the Southern Plateau, being most marked in summer because it is a heat Low. This pre-requisite, then, to the development of "hot northers" is always present and available, but the other essential, the anti-cyclone, extending from British Columbia southward to include the Middle Plateau region, depends upon much more variable conditions, and therefore hot waves are not of frequent occurrence.

(13) A brief description of cold-westers, as I choose to call them, or the cold waves of summer, will emphasize the importance of the relations of cyclonic and anti-cyclonic circulation in the production of these atmospheric changes. A typical cold-wester chart exhibits the High central in Northern California, or off the coast near San Francisco. The Low is central in eastern Nevada and Utah. The barometric pressure ranges from 30.00 to 30.15 in the former, and from 29.80 to 29.40 in the latter. The winds shift to westerly with increasing force, becoming brisk to high in northern California and Nevada. The air rushes inland from the ocean. The humidity rapidly increases and heavy cloudiness becomes general throughout California and Nevada. Light rains become frequent, turning to snow in

the mountains, especially if the cold-wester continues two or three days. The temperature falls very low and frosts occur where the air is sufficiently clear and quiet. The following are three notable cases of cold-westers. On May 15th, 1883, with the High (30.00) at San Francisco and the Low (below 29.80) in Utah, the temperature fell to 39.5° at Los Angelos, Visalia 38°, Red Bluff 44°, Sacramento 48°, and Winnemucca 40°. Light rains followed by severe frosts occurred in California and Nevada. On June 6th, 1887, with the high (over 30.00) at San Francisco, and the low (below 29.90) in Utah, the temperature fell to 46° at Los Angeles, Sacramento 48°, Fort Bidwell, 32°, and Winnemucca 32°. Light rain followed by frosts occurred in Northern California and Nevada. On May 9th, 1887, with the High (over 30.10) near San Francisco, and the Low (below 29.60) in Utah, the temperature fell to 24° at Fort Bidwell, Eureka 38°, Red Bluff 40°, Sacramento 41°, Keeler 40°, Salt Lake City 39°, Winnemucca 16.80, Roseburg 33°, Portland 37°, Boise City 26°. Severe frosts occurred in California, Nevada and Oregon. Light rains in the valleys and snow in the mountains. This was one of the most remarkable cold-westers ever experienced on the Pacific Coast.

(14) Cold-westers usually continue longer and occur more frequently than "hot northers," probably due to the fact that the necessary positions of the High and Low are more easily accomplished in the development of the former. That is, the Low in Utah and eastern Nevada is more likely to occur than on the southwest coast of California. The High is more likely to appear off the California coast than over the middle plateau. This relation would be a natural one in summer. The frequency and severity of cold-westers depends upon the frequency and energy of cyclonic movements over British Columbia. Such effect was notably illustrated in May, 1891. The Low was almost continually present in Nevada and Utah. The month was cold, damp and cloudy, with frequent rain in California and Nevada, and snow in the mountains as late as the 30th.

CAUSES.

(1) The existence of high barometric pressure over Nevada, Utah and the North Pacific Region, checks the flow of air from the ocean inland. The wind currents shift from west to north and the force decreases.

(2) When the eastward motion from the ocean is prevented the air over the land is deprived of its source of moisture.

Therefore the skies are cloudless and no screen is offered to the sun's heat. The earth heats up rapidly, which in turn warms the air resting upon it.

(3) Under the influence of a general and continued movement of the air southward, the atmosphere in the cultivated valleys of California is constantly replenished from the intensely heated alkali plains of Nevada and of the southeastern portion of California, and from the lava beds and sand deserts of Southeastern Oregon and Northwestern California. Over these regions not a cloud is observed during the prevalence of a hot wave, and a basin of water placed in the sun upon the sand, will soon become too hot for the hand to bear. Some persons have reported that the heat has been sufficient, under such circumstances, to boil the water.

(4) The development of a cold-wester requires the same kind of cyclonic and anti-cyclonic circulation as in the formation of a "hot norther," but a decided change in the geographical location of the High and Low. Such a change carries over the land large masses of moist air from the ocean, the vapor of which, under the influence of the ascensional currents over the hot valleys and plateaus of the interior, is rapidly condensed by the cold of elevation. Heavy clouds form, and if the wester continues, rain in the valleys and snow in the mountains follow. The clouds clear away at night and radiation is rapid with low temperatures. With the appearance of the sun the clouds again form, the earth is screened and does not recover the heat lost by radiation, and therefore the air resting upon it is chilly and uncomfortable. In the case of "hot northers" the loss by radiation at night, which ranges from 20° to 50° is quickly regained during the day because of the entire absence of clouds.

REMEDY.

(1) The damage inflicted by hot northers on vegetation can, I believe, be obviated, in great measure, by spraying the plants or trees with water. The air about them will be cooled by evaporation and the blighting effect of the heat counteracted. The plan is practicable, especially with orchards, such as oranges, lemons, prunes, apricots, almonds, English walnuts, figs, etc. The establishment of these orchards is a matter of great expense and the large profits from them justify considerable expenditure for protection. Forms of apparatus are already in use (operated by man or horse-power) for other purposes, which could be readily adapted to the work here required.

(2) The planting of rapidly growing trees, like the eucalyptus, which will serve as wind-breaks in protecting fields of grain and orchards. As the danger comes from the north the trees should be planted in rows east and west. If the area to be protected is very large several rows at intervals of a few hundred rods could be planted. These rows of trees could be utilized as division fences for fields. The spraying with water of these rows of lofty trees would make them still more effective in protecting the crops.

(3) It would seem practicable to employ insurance as a means of protection. Insurance of this character is a perfectly legitimate business and can be conducted as safely and profitably as hazards against life and limb on rail or water.

(4) It is practicable to forecast the approach of "hot northers," and the warning can be furnished by telegraph from 12 to 24 hours in advance of the change. This matter should receive the earnest attention of the United States Weather Bureau.

(5) The daily weather map should be given a large circulation and the people instructed in its practical use. In connection with this daily publication, typical "hot-norther" charts could be prepared for purposes of reference and to guide the student of the daily weather map as to the development of conditions signifying the probable occurrence of hot waves. Thus the farmer and horticulturist could prepare themselves with more intelligence and satisfaction for impending changes and the forecasts of the central meteorological office could be made more effective in their hands.

SAN FRANCISCO, CAL., June 15th, 1891.

ALTITUDE AND HAY-FEVER.

BY W. J. HERDMAN, M. D.

Elevated resorts, no matter in what part of the country they are located, have, as a rule, gained a reputation for a curative and prophylactic influence upon hay-fever. Thus the White Mountains, the Adirondacks, Roan Mountain, and many places in elevated regions beyond the Mississippi have well founded claims to immunity from those conditions which occasion this periodic disorder at this season.

The reasons assigned for the blessed relief experienced by the afflicted who flee to the mountains in mid-summer to escape a

recurrence of this distressing malady are, the purity of the atmosphere from all irritating particles, either organic or inorganic, which in contact with over-sensitive mucous membranes of the nose, throat, or bronchi might excite inflammation, and the tonic effects of a cooler, dryer atmosphere in increasing the body resistance to such irritants.

In considering the comparative value of the various factors which make up the conditions resulting in benefit to the patient who finds relief from this disorder at one of the many mountain resorts, it has seemed to us that writers have uniformly failed to attach to the effects of altitude alone the importance which it deserves.

It is highly probable that the direct action of altitude upon the patient is attended by as much, if not more benefit in warding off an attack of hay fever than the freedom it insures from irritating particles.

The majority of mankind in the midst of conditions believed to be causative of this disease are not victims of it. This must be due to some capacity for resistance in them that is not possessed by their less fortunate neighbors. The physiological state and action of their air-passages differ in some manner from those who are subject to the disease. A greater irritability, a proneness to catarrhal congestion and inflammation in the mucous membranes lining the air passages constitutes this difference. The seat of this susceptibility may be primarily in the nervous system—a vaso-motor instability—or it may be due to some local change in the membranes themselves. Whichever may be the starting point for the phenomena these are marked by an increased blood flow to the parts affected and the result is congestion and exudation. The many disagreeable symptoms of which these sufferers complain are the immediate consequence of this increased and abnormal vascularity.

Repeated attacks of catarrhal inflammation weaken the resistance of the membranes involved, lowering their tone, and the nerves distributed to the part become so over-sensitive that they respond excessively to the slightest stimulus and in consequence a passive congestion becomes a constant condition of these membranes. Any cause, therefore, that will operate to prevent or retard this local congestion will be a very important factor in effecting a cure. A considerable altitude has just this effect. The decreased atmospheric pressure acts upon the vascular system as a constant derivative. It dilates the cutaneous blood-

vessels and has the effect of a continuous and decided vaso-motor counter irritant preventing, thereby, the conditions favorable to a local congestion of the mucous membranes of the upper air passages.

That the subsidence of congestion is an important and real factor among the curative influences of elevated resorts upon this malady, is demonstrated and confirmed by witnessing the relief afforded in acute attacks of this disease by medicinal and physiological means which have a similar effect in equalizing the circulation, although with much less constancy than when brought about by the influence of altitude.

Aconite, belladonna, the bromides and the many astringent and sedative sprays and douches that are advised in this disorder are of service in diminishing congestion and allaying its consequent ill effects, while active muscular exercise, especially with the arms, at the commencement of an acute attack of hay-fever coryza, will if it does not wholly arrest the attack, greatly mitigate its severity, diminishing the distressing tightness in the nos-nostrils, throat and chest and checking the secretion of mucous.

What we can thus do temporarily and fitfully by the appli-application of medicinal agents and purposive muscular effort, is done constantly and effectively by the diminished atmospheric pressure of altitude, and hence we find in elevated resorts an additional factor in the cure of this disorder which is not possessed by any low-land resort, no matter how favorably it may be located for securing purity of atmosphere. Purity of atmosphere might alone prove sufficient but when this can be secured together with the beneficial effects of altitude it offers increased advantages.

The atmosphere at an elevation above 3,000 feet has been found by several experimenters to be comparatively free from pollen no matter what the direction of the wind, while a change of wind at a lower level, a land breeze at a sea-side or lake resort might become laden with such plant products and occasion a sudden outbreak of the disorder among its residents, as has frequently happened in such places. But even should the irritating particles be found in greater abundance in the atmosphere of mountains, the altitude, for the reasons above stated render the patient much less susceptible to their peculiar influence. But it should be noticed in this connection that the elevation chosen with a view of securing immunity from hay-fever should be a moderate and not extremely high altitude, nor

one in which the body is subjected to prolonged insolation. Such conditions are known to increase nervous irritability and in that manner might operate to counteract the good that is sought. An altitude between three thousand and six thousand feet, and in a locality not too free from moisture, and with an equable diurnal temperature would seem the ideal resort for those afflicted with a tendency to hay fever. Frequent precipitation of moisture is itself of service in cleansing the atmosphere while a moderate amount of moisture in the atmosphere also favors electric conductivity and is sedative in its influence upon the nervous system.

CORRESPONDENCE.

SUNSET PHENOMENON.

To the Editors: On the evening of the 18th inst. my attention was attracted to a peculiar phenomenon, for which for a time I was unable to account.

On the eastern sky there were what appeared to be radiant beams of light emanating and diverging from a certain point upon the horizon. The appearance presented was quite similar to the shadows of clouds as are frequently seen projected upon the sky shortly after sunset, and before sunrise. In this instance, however, the sun was at an opposite point of the compass from where the phenomenon appeared, hence it was apparently not the source from which the light emanated. The sky at the time, from the point of observation westward was covered with cumulo-stratus clouds and a heavy rain was passing to the northwestward, while near the zenith it was quite clear and in the east was overcast with cirro-stratus clouds. There were no shadows visible in the west, for the entire sky, in that direction and the sun were obscured. Evidently clouds in the west which were not visible from the point of observation, cast shadows which, with alternate beams of light passed overhead in parallel lines, but which as a result of perspective were rendered invisible near the zenith and then converged and made visible near the eastern horizon. This view is sustained by the fact that the beams had a lateral movement toward the north,—first appearing at a point south of their apparent center and then gradually moving northward and disap-

pearing at a point north of that center. This movement corresponded with the direction in which the clouds in the west were moving.

W. J. WAMBAUGH.

AUGUSTA, GA., July 20, 1891.

CURRENT NOTES.

CAUSE OF THUNDER.—Many theories have been offered in explanation of the phenomenon of thunder. Here is Professor Hirn's description: "The sound which is known as thunder is due simply to the fact that the air traversed by an electric spark, that is, a flash of lightning, is suddenly raised to a very high temperature and has its volume, moreover, considerably increased. The column of gas thus suddenly heated and exhausted is sometimes several miles long, and as the duration of the flash is not over the millionth of a second, it follows that the noise bursts forth at once from the whole column, though for an observer at any one place, it commences where the lightning flash is at the least distance. In precise terms, the beginning of the thunderclap gives the minimum distance of the lightning, and the duration of the rolling of the thunder the length of the column of heated air. Professor Hirn also remarks that when a flash of lightning strikes the ground, it is not necessarily from the place struck that the first noise is heard. Again he points out that a bullet whistles in traversing the air, so that we can, to a certain extent, follow its flight. The same thing also happens with a falling meteorite just before striking the earth. The noise actually heard has been compared to the sound produced when one tears linen; it is due, really, to the fact that the air rapidly pushed on one side of the projectile in front, whether bullet or meteorite, quickly rushes back to fill the gap left in the rear."

LOCAL STORMS NORTHEAST OF A LOW.—On June 1st, at 8 P. M., a center of low pressure lay to the southwest of Nebraska and Kansas while a high pressure center was to the north of Lake Superior and another off the south Atlantic coast. The condition was nearly the same twenty-four hours later. At about 3 P. M., of the 2d, a well-marked tornado, with funnel-cloud and with path about 100 feet wide, appeared at Watertown, South Dakota, and a smaller one at Hazel on the eastern border of the same state. Meantime, thunder-storms and heavy rains seem to have prevailed from Montana to Ohio and New England. The

weather conditions proved very favorable to the formation of local storms, and the remarkable feature is that these were north of the latitude of the low center and especially northeast of it.

The next day the center of low pressure moved over Illinois and Indiana. A tornado occurred in Kentucky (southeast), and heavy rain in Ohio and Michigan (east and northeast). Meantime, the center of high pressure north and northwest of Lake Superior remained unchanged in position and a very severe gale occurred on that lake. Newspaper reports gave the height of the waves at 30 to 40 feet (from hollow to crest, probably). This is a very unusual run for the waves on this limited body of water.

Squalls on the southern end of Lake Michigan on the 3d, caused remarkable rises and falls on the small Chicago river, with corresponding backward and forward currents in the usually very sluggish stream. The water rose and fell from 18 inches to 26, two or three times an hour and this was kept up for several hours. The greatest range reported was 44 inches.

"The Relation of High Winds to Barometric Pressure, from observations carried out at the Ben Nevis Observatory," was the subject of a paper from Dr. Alexander Buchan, at a meeting of the Royal Society of Edinburgh, on the 2d of March, 1891. This was a question, Dr. Buchan said, which had been much discussed in recent years—some meteorologists maintaining that the influence of high winds was to depress the barometer, others that it was to raise the barometer, and several others, again, that it had practically no effect whatever. In the discussion of the Ben Nevis observations, particularly from the time that hourly observations began to be obtained from the low-level observatory at Fort-William, in July last, the first question that appeared to him calling for thorough investigation was this question of the relation of the winds to the readings of the barometer, inasmuch as, till this relation be approximately determined, the proper discussion of nearly the whole of the observations cannot be satisfactorily proceeded with. This arose from the manifest disturbing influence of high winds upon the readings of the barometer at the top of the Ben. Since the two observatories are only about four miles apart in horizontal distance they are virtually one observatory as regards geographical distribution of pressure; and as the observatory at the top was peculiarly exposed to high winds, the violence of many of which those living on lower levels could

really form no conception, while the low-level observatory at Fort-William was much sheltered from winds, the two presented conditions for an exact determination of the question of the influence of winds on the barometer, from data which had not hitherto been available. The observations at the top were made on Beaufort's wind-scale, ranging from 0, representing the calms, to 12, the greatest hurricane likely to occur. These observations had been carefully compared in connection with the registrations of a modification of Robinson's anemometer, which had been specially constructed by Professor Chrystal to meet the exigencies of observing at the top of the Ben. An elaborate comparison had been communicated by Mr. Omond to a meeting of the Royal Society some time ago, in a paper in which he had arrived at the equivalent in miles per hour for each degree of Beaufort's scale. The next step followed in the present inquiry was to reduce the observations at both observatories to sea-level, and thereafter to enter the differences between the two barometers in columns headed 0, 1, 2, etc., of Beaufort's scale. This had been done for the six months ending January last; and as it was desirable to increase the number of observations at the higher velocities in order to obtain good averages, the observations made five times daily at Fort-William from the beginning of 1885 were compared with those made at the same hours at the top of the Ben, when the wind was at 5 and other velocities up to 11. From these results monthly averages of deviations of the two barometers were deduced, with the result that in all cases a reduced barometer for the top of the hill read lower than that at Fort-William, and the amount is proportioned to the force of the wind. Thus, in calm weather the Ben Nevis barometer was only one-thousandth of an inch lower than that of Fort-William, and as the velocity of the wind increased, the depression gradually became greater up to force 4, when it was fourteen-thousandths lower. From this point it more rapidly increased, till at force 7 the depression was half the tenth of an inch; at force 9, fully the tenth of an inch; and at force 11, a tenth and a half of an inch. These differences, being exhibited in a diagram, showed a remarkable curve of depression corresponding with increased velocity of wind. The results, Dr. Buchan pointed out, might be put to important uses in meteorology, particularly in endeavoring to establish the relation between the barometric gradient and wind-velocity in storms. Hitherto this relation had been

attempted to be established from the results as observed—though, it had to be confessed, with not very satisfactory results. Now, however, by applying corrections in accordance with what had been arrived at, this important practical question in meteorology could be attacked with good hopes of success. Dr. Buchan further pointed out that, as regarded the mean distribution of pressure over the British Isles, the lower pressure hitherto determined at places on the West Coast peculiarly exposed to strong winds and storms might be due not so much to a natural depression of the barometer in these regions as to the lowering of the barometer by the wind-force that swept past the stations where the observations were made.—*Scot. Geog. Mag.*

Balloon Ascent in an Anticyclone.—Lieut. Gross ascended from Berlin on February 24, 1891, while a maximum of pressure occupied central Europe. The balloon rose at 10:52 a. m. and descended at 5:22 p. m. in Döbeln, after a fairly straight course southward in which it ascended gradually to an elevation of about 1,400 meters. Clouds lay over Berlin at a height of 150 meters and with a thickness of 100 meters. The balloon showed an inclination to swim in their upper surface and was released only by energetic outcast of ballast. The upper surface of the cloudlayer was roughened by heads of cumulus thirty to fifty meters high. The shadow of the balloon formed on the clouds an aureole with fairly strong colors. In part of the course of the balloon the clouds were replaced by a dense but thin fog. The wind was from the north above the clouds; it was fairly constant but became stronger with increase of elevation. At the surface, up to and in the clouds, the wind was light and SSW at the start and it was again SSW when descent was made at Döbeln.

With the sling-thermometer the temperature was —3° C., at the start and in the clouds. At the upper cloud-surface it rose to —1°. The temperature then rose with increase of elevation until at about 600 meters it was +10°. The temperature was higher over the clouds than elsewhere. At the descent the temperature fell from +7° to +3°.—The above is condensed from the report given in pages 88 to 91 of Volume X. of the *Zeitschrift für Luftschiffahrt.*

Experiments in Atmospheric Electricity at Blue Hill Observatory.—Continuous observations of atmospheric elec-

tricity have only been made at a few of the best equipped astronomical and meteorological observatories.

At the Collège de France, in Paris, the curves have been continued since 1881, at Perpignan since 1882, and at Greenwich, Lyons and the Parc St. Maur, (near Paris), likewise for long poriods. In the United States continuous records were obtained by the Signal Service at Baltimore for a period of three years, and at Worcester aud Amherst, observations have been made for short periods. The chief cause of this paucity of observations is undoubtedly the difficulty of maintaining and manipulating the photographic register. The expense of a proper equipment is considerable, and the various difficulties that arise in installing the apparatus make it impossible to use the method elsewhere than in a well equipped observatory. The ordinary form of Mascart self-register (and this is about the only apparatus free from grave theoretical errors) requires for a successful record, a dark room, stone piers, constant hygrometric and temperature conditions and the fixing of the record of photography. Observations of the potential of the air can never therefore be general with such apparatus. It is also impossible where photography is used to know what the value of the potential is at any moment, a very important desideratum. The electrometer for successful general use, as for example, for use at the various stations of the Weather Service, at experimental stations, etc., must first of all, be one giving a record that can be easily read at any hour of the day.

These considerations have led to the construction of a new type of electrometer known as the "Multiple Quadrant Electrometer" and a series of experiments to test its efficiency are being made at Blue Hill Observatory. The instrument is simply an enlarged Quadrant Electrometer, with the parts all so arranged as to be convenient of access, and instead of the four quadrants and small single aluminium needle, eighty quadrants and a needle with twenty blades is used; or it can be arranged to have forty quadrants and a ten bladed needle. The great advantage of the curve given by the mechanical registering of the movements of the needle, is, as has been said, the possibility of seeing at each moment what variations in the potential of the air are occurring, and the possibility of directly comparing these changes with the changes in atmospheric pressure, temperature, humidity, wind direction, velocity, etc.

Thus far some excellent results have been obtained and while

in sensitiveness, of course nothing can exceed or, indeed, even equal the bifilar suspension and ground glass scale (while photography can be equally sensitive, still it is worth while to remember that in practice, a very feeble light is generally used and the photographic record, while very delicate yet frequently has no record of the very rapid fluctuations) the sensitiveness of the new electrometer has been greater than was expected. The fluctuations due to distant thunder storms are easily discernible in the record.

Some very interesting experiments are also in progress at Blue Hill, with two Mascart self-registering outfits, one at the summit, and one at the base, 126 metres below the summit and 1,178 metres northwest, using exactly similar instruments and methods to test whether or not a synchronism can be found in the daily periods and in the accidental fluctuations. A. M.

BOOK NOTICES.

General Greely's Report for 1890.*—This is the report for the fiscal year ending June 30, 1890. During the year approved observers in charge of stations have been permitted to make local forecasts. A conservative course was followed and permission given at 31 stations to predict weather and temperature, while at 55 others only temperature was predicted. The percentages of verifications at Washington were 84.4 for weather, 78.7 for temperature, and 82.6 general average. This shows an improvement of 17 per cent. over the previous year. The verification percentage for storm-signals was 67.1—practically the same as for the previous year. We are glad to see that General Greely speaks warmly in praise of the cold-wave forecasting, though the percentage of verification is low. River observations are made for twenty-seven rivers, at seventy-one stations, and there are besides forty-seven supplementary rainfall stations for this part of the work of the Service. The forecasts of floods have attained a high degree of accuracy and the officer in charge proposes to predict for Cincinnati three days in advance.

The number of weather maps issued was over one million of which only about 18 per cent. were sent out from Washington

* Annual Report of the Chief Signal Officer to the Secretary of War for the year 1890. Washington, 1890. Octavo, 712 pages and many maps.

City. In 1886–'87 the number was only 178,000 and 65 per cent. were sent out from Washington. There were twenty-eight state weather services within the jurisdiction of the national service,—including the New England service covering several states. Five hundred meteorological stations of all classes were in operation in the year reported on; of these General Greely reports twenty-six, at which self-registering instruments are employed. The work of the record division is unusually full and comprehensive. Among other things a complete account is making of all observations ever taken at the individual stations. The library of the service now contains about 12,000 volumes exclusive of pamphlets.

The scientific work of the Service during the year is well represented in the appendices to this volume. The exception to this is in the case of Professor Abbe whose "Deductive Methods" were published in the preceding report and his work as a member of the scientific expedition to the west coast of Africa was published elsewhere or still awaits publication. Capt. Allen has a memoir (Appendix 24) on the improvement of forecasts of rain. Lieutenant Finley's studies of tornadoes and of storm-tracks, ice and fog on the North Atlantic were published elsewhere. Professors Marvin and Hazen made interesting studies of humidity measurements, and their results are included in Appendix 18. Professor Marvin has also (Appendix 25) continued his study of measurement of wind velocities, and Professor Hazen (Appendix 26) has made an especial study of the destructiveness of tornadoes. He finds them over estimated and makes the average mortality from them only 102.

The Report of the Chief of Engineers for 1890 contains 3,718 octavo pages, besides table of contents and index. It contains many things of geographical and meteorological interest, though it requires some experience to find them. Among these is an interesting discussion of the question of the effect on river-beds of the long-continued use of levees. This begins on page 3,093, and General Comstock, the reporter, concludes that the idea that rivers with levees gradually elevate their beds until they may be higher than the surrounding country is a fiction of purely literary origin.

On page 3,585 are given important data as to the mean height above mean tide at New York of the levels of the Great Lakes. The adopted levels, as the result of observations from 1860 to

1875 inclusive, are as follows: Lake Ontario, 246.61 feet; Lake Erie, 572.86 feet; Lakes Huron and Michigan, 581.28 feet; Lake Superior, (1871–1875) 601.78 feet. Lake Superior was at its lowest known stage in 1819, when it was about two feet lower than the mean, at its highest in 1838, when it was about 3.5 feet higher than the mean. The low water in Lake Erie for 1819 stood at 569.70+ or 3.16 feet below mean.

REPERTORIUM FÜR METEOROLOGIE.*—These two huge volumes exceed in size most of the preceding ones of the same series, and their importance can be estimated by a glance at the following tables of contents, given as translations. The complete volumes can be obtained at the price of 31 marks and 29 marks 25 pfen., respectively, at Voss's Sortiment (G. Haessel) in Leipsig; and the individual papers can be purchased separately at very moderate prices. It is, perhaps, not generally known that the individual memoirs are published at irregular intervals and can usually be secured in advance of the publication of the collected volume. For instance, at the present writing I have just received No. 9 of Band XIV, but it will be still some months before the complete volume will be ready for distribution. I wish to urge upon American Meteorological investigators the importance of studying these Russian memoirs as patterns for similar and much needed contributions from this country.

CONTENTS OF VOL. XII.

I. E. Stelling. On the velocity, surface oscillations and amount of water of the Angara at Irkutsk. 40 pages.

II. A. Schönrock. Results of the meteorological observations in Russia during the eclipse of the sun August 19, 1887. (With a graphical table). 15 pages.

III. J. Kiersnowsky. On the daily and yearly march, and the distribution of wind velocity in the Russian Empire. (With three charts). 94 pages.

IV. A. Wosnessensky. On the earthquake in and around Wernyj in 1887 and its relation to meteorological events. (With a graphical table). 16 pages.

V. J. Mielberg. Magnetic observations in the highlands of Armenia in 1887. 19 pages.

VI. M. Rykatschew. Results of the anemograph in Kron-

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*Band XII, St. Petersburg. 1889. Band XIII, St. Petersberg, 1890. Published by the Imperial Academy of Sciences, and Edited by Dr. Heinrich Wild.

stadt for 1883–1885, and comparison with the results of the anemograph in St. Petersburg. (With two tables). 87 pages.

VII. B. Sresnewsky. The storms on the Black and Azov Seas. (With three charts). 75 pages.

VIII. P. A. Müller. On the variations of the earth's magnetism in St. Petersburg and Pawlowsk 1873–1885. (With three graphical tables). 67 pages.

IX. A. Kaminsky. The comparability of the observations of precipitation in Russia in Europe. 32 pages.

X. B. Kiersnowsky. The cyclone paths in Russia for the years 1884–1886. (With 12 charts). 29 pages.

XI. H. Wild. On Assmann's new method for ascertaining the true air temperature. 18 pages.

XII. P. A. Müller. Observations of Inclination in the Observatory of Katharinenburg from 1837 to 1885. 28 pages.

XIII. E. Berg. Investigation of a winter thunder storm. (With a plate). 28 pages.

XIV. H. Wild. Annual report of the Physical Central Observatory for 1887–1888. 245 pages.

ADDITIONAL.

I. B. Sresnewsky. On the graphical determination of the yearly march of the temperature from monthly means. 6 pages.

II. H. Abels. Observations of Inclination in Ssurgut, Obdorsk and Kondinsk. 4 pages.

CONTENTS OF VOL. XIII.

I. A. Schönrock. Compilation of the results of repeated comparisons of normal barometers in Europe. 28 pages.

II. E. Leyst. Investigations on the influence of the terminal readings of the extreme thermometer on the extreme temperatures and daily mean of temperature determined from them. 54 pages.

III. E. K. Assafrey. Magnetic observations in the government of Eriwaw in 1888. 19 pages.

IV. E. Stelling. Magnetic observations in the Lena Region in the summer of 1888, and remarks on the secular change of the elements of the earth's magnetism there. 20 pages.

V. E. Berg. The thunder storms in Russia in 1886. (With table). 51 pages.

VI. B. Sresnewsky. On the heaping up of the snow by wind on the railroads in Russia. (With three charts). 74 pages.

VII. E. Leyst. On the ground temperature in Pawlowsk. (With three tables). 311 pages.

VIII. H. Wild. Ombrograph and Atmograph. (With table). 14 pages.

IX. W. Friedrichs. Investigations on the usefulness of the Richard Hygrograph having a substance of horn. (With one graphical table). 40 pages.

X. B. Kiersnowsky. On the foretelling of the nightly temperature minimum from observations in Astrachan, Ehssawetgrad and Warschan. (With one graphical table). 22 pages.

XI. A. Schönrock. Special investigation of thunder storms in Russia in 1888. (With one chart). 18 pages.

XII. H. Wild. Year's report of the Physical Central Observatory for 1889. 52 pages.

ADDITIONAL.

I. J. Kleiber. On the determination of the true march of meteorological elements from incomplete mean values. 7 pages.

II. H. Abels. Contribution to the question, whether in the bifilar magnetometer silk or metal threads are to be used. 10 pages.

In reviewing a former volume of Wild's Repertorium, the idea was expressed that perhaps these volumes would now become annuals, and in the last of the present volumes this view is substantiated by Director Wild, who says that the Russian Meteorological Service has assumed such large proportions that an Annual Report has become necessary. For a number of years it has been feared that the increased centralization which has been occupying the Russian leaders would result in a withdrawal from the official use of French and German in its scientific publications. Meteorologists in general would greatly suffer if the Repertorium were no longer published in a language widely understood. The danger of the change from a German text to a Russian text is, for the present, at least averted by the publication of a complete Russian edition which begins with Vol. XIII. Let us hope that this means a continued duplicate publication of the work, and that with the successful issue of the Russian edition for home use, there will be no temptation on the part of retrenching officials to suppress the German edition which has, for so many years, stood at the head of such publications in the opinion of working meteorologists.

In Director Wild's Annual Report for 1887–88, as given in Band XII., we find that there is a steadily increasing interest in meteorology and its application manifested by the Russian

government. And this feeling Dr. Wild has done his best to strengthen by encouraging the workers under him to utilize their utmost capacity for work. We sometimes wonder how the small corps of meteorologists at St. Petersburg (and vicinity) are able to accomplish so much; but when Dr. Wild states that the members of the Pawlowsk observatory were working twelve hours daily at their official duties and *voluntary* extra investigations, the secret of their success is apparent. Such enthusiasm is rare, however.

In the physical cabinet of the Central observatory a great change has been made in the amount of possible work, by the introduction of electric lights; which permit day or night work under the same conditions of illumination which is so necessary in making refined measurements. This is especially valuable in the use of the normal barometer which can now be read throughout the year by making the observations after midnight when no vehicles are passing. Previously, this instrument could only be used in the winter time when sleighs were used and the snow prevented ground vibrations from disturbing the mercury surface. During the year 1888 a complete series of hourly observations was undertaken at Pawlowsk, which must have been an enormous undertaking; for, every hour twenty-four thermometers were read, and from one to sixteen times a day apparently forty additional thermometers were read. The underground observations were the most valuable of this series, and Dr. Leyst has given a very full and satisfactory discussion of them in his memoir in Band XIII. of the Repertorium. The experimental work at Pawlowsk is always of great interest and deserves wide study on the part of working meteorologists. For instance, the hourly observation of amount of clouds by means of a cone-shaped frame-work of rings, (with the eye at the apex) show that an error of nearly 10 per cent. of the observed amount of cloudiness probably occurs by the old method. The further mention of important work which Director Wild records on each page of his reports cannot be noticed in this short review. We must notice, however, that a daily bulletin with double weather chart is now printed, and it is hoped that a mountain observatory will be erected on the Tschatyrdagh (4,984 feet altitude) with an affiliated base station. There are now in the Russian service about four hundred second-class stations; about six hundred third, and in all about eight hundred where thunder storm observations are made. F. WALDO.